PROPOSAL INFORMATION PACKAGE (PIP)
FOR BROAD AGENCY ANNOUNCEMENT (BAA) 02-025
ENTITLED "FISCAL YEAR 2003 MULTIDISCIPLINARY RESEARCH PROGRAM OF THE UNIVERSITY RESEARCH INITIATIVE (MURI)"

A. Content and Form of Proposal – The proposal must be complete and self-contained to qualify for review.

The Department of Defense (DoD) through the MURI program sponsored by the Office of Deputy Under Secretary of Defense for Laboratories and Basic Research (ODUSD(LABS)), supports U.S. universities to perform basic science and engineering research and related education in science and engineering areas critical to national defense. For this reason, the proposal must adequately describe both the research and research-related education, so that an assessment can be made on relevance to DoD research interests and responsiveness to the guidance within this announcement.

Each proposal should be TYPED, 10-12 POINT FONT, one sided, on 8 1/2 x 11 inch white paper, and stapled or bound. Separate attachments, such as institutional brochures or reprints, will not be accepted. Plastic covers or binders should not be used. Proposals submitted in whole or in part by electronic media (computer disk or tape, facsimile machine, electronic mail, etc.) will not be accepted.

The proposal submission process is in two stages. First, prospective proposers are encouraged to submit white papers. The reason for requesting the white papers is to minimize the labor and cost associated with the production of detailed full proposals that have very little chance of being selected for funding. Second, based on informal feedback from the program manager, interested proposers may then submit the full detailed proposal.

1. White Paper

White papers describing briefly the proposed research project should be sent to the responsible Research Topic Chiefs in the agency specified for the topic. The white paper should be no more than four (4) pages, with a detailed summary of the research that would be proposed and a list of the potential team members. Based on an assessment of the white papers, the responsible Research Topic Chief will provide informal feedback to the proposers to encourage or discourage them from submitting full proposals. All interested proposers are requested to submit white papers in order to receive informal feedback. White papers arriving after the deadline may not receive any informal feedback. However, all proposals submitted under the terms and conditions cited in the BAA will be reviewed regardless of the disposition (or lack) of white papers.

2. Proposal

The proposal must include the following:

Cover. A completed proposal cover (Appendix A). No other sheets of paper should precede this cover.

Abstract. Include a concise (not to exceed one page) abstract that describes the research and research-related education that would be supported by a MURI grant.

Text. The technical portion of the proposal should be limited to no more than 25 pages and should:

a. Describe in detail the basic science and/or engineering research to be undertaken. State the objectives and approach, including how data will be analyzed and interpreted. Discuss the relationship of the proposed research to state-of-the-art knowledge in the field and to related efforts in progress elsewhere. Include appropriate literature citations. Discuss the nature of expected results. Discuss potential applications to defense missions and requirements.

b. Describe the facilities available for accomplishment of the proposed research and related education objectives. Describe any capital equipment planned for acquisition under this program and its application to the proposed research. (When possible, capital equipment should be purchased early in the first year of the grant.)

c. Describe plans for the research training of students. Include number of full time equivalent graduate students to be supported each year and undergraduates if any. Discuss the involvement of any other students.

d. Describe in detail proposed subawards to other eligible universities or relevant collaborations (planned or in place) with government organizations, industry, or other appropriate institutions. Particularly describe how collaborations are expected to facilitate the transition of research results to applications. Descriptions of industrial collaborations should explain how the proposed research will impact the company's research and/or product development activities. If subawards to other universities are proposed, make clear the division of research activities and provide detailed budgets for the proposed subawards.

e. List the amount of funding and describe the research activities of the principal investigator and co-investigators in on-going and pending research projects, whether or not acting as principal investigator in these other projects, and their relationship to the proposed effort.

f. Identify other parties to whom the proposal has been or will be sent, including agency contact information.

Personnel. Describe the qualifications and availability of the principal investigator and co-investigators to conduct the proposed research. Include curriculum vitae and other experiences relevant to the proposed research effort. For the MURI team, one individual should be designated as the principal investigator for the award and for purposes of technical responsibility and contact.

<u>Budget.</u> The financial portion of the proposal should contain cost estimates sufficiently detailed for meaningful evaluation, including cost details for proposed subawards. Cost sharing is not required. For budget purposes, use an award start date of 1 May 2003. The costs should be broken down to reflect funding increment periods of: seven months (1 May 03 to 30 Nov 03), twelve months (1 Dec 03 to 30 Nov 04), twelve months (1 Dec 04 to 30 Nov 05), and five months (1 Dec 05 to 30 Apr 06) for the three-year base grant. The budget should also include two additional option years broken down to the following funding periods: seven months (1 May 06 to 30 Nov 06), twelve months (1 Dec 06 to 30 Nov 07), and five months (1 Dec 07 to 30 Apr 08). The annual budget should be relatively flat, i.e. about the same amount per year. However, if there is anticipated difficulty in effectively spending the funds at the steady state rate for the entire first budgeted period, the seven month's budget in the first period can be proportionally reduced to account for start-up effects. Elements of the budget should include:

a. Time being charged to the program, for whom (principal investigator, co-investigator, graduate students, undergraduates, etc.), and the commensurate salaries and benefits. Allowable charges for graduate research assistants include salary/stipend, appropriate research costs, and any tuition cost normally chargable to other research grants. Allowable charges for undergraduate students include salary and research training costs, but not tuition.

b. Estimate of material and operating costs.

c. Cost of equipment, based on most recent quotation and broken down in sufficient detail for evaluation. Indicate the proposed source of the equipment. Include a name and phone number of a contact at that source or a website address that lists the equipment and its cost. Capital equipment costs should be budgeted primarily within the first funding increment. If capital equipment is budgeted within subsequent increments, justifiable reason must be given.

d. Travel costs. Include destinations, purposes, and the relevance to stated research program objectives.

e. Costs of publications and reports.

f. Subaward costs and type (the portion of research work to be subawarded). Note that the subaward of funds among all university performers responding as a multi-university team must be described fully and in detail in both the text and budget sections. Note that application of indirect cost (facilities and administration) to subawards shall be governed by A-21 cost principles.

g. Consultant fees (indicating daily or hourly rate) and travel expenses. Include a description of the nature of and the need for any consultant's participation. Strong justification must be provided, and consultants are to be used only under exceptional circumstances where absolutely no equivalent expertise can be found at a university.

h. Communications costs not included in overhead.

i. Other direct costs.

j. Indirect costs (facilities and administration).

k. Total costs for each budgeted period, a total for the initial three years, a total for the additional two-year option, and a total for the entire proposed program.

Acknowledgement Receipt. Complete Appendix B to the PIP, if desired.

B. Evaluation Criteria-Proposals will be evaluated using the following criteria.

The first three evaluation factors are of equal importance:

(1) Scientific and technical merits of the proposed basic science and/or engineering research;

(2) Relevance and potential contributions of the research to Department of Defense missions; and

(3) Impact of plans to enhance the institution's ability to perform defense-relevant research and to train, through the proposed research, students in science and/or engineering (for example, by acquiring or refurbishing equipment that can support DoD research and research-related educational objectives).

Other evaluation criteria, of lesser importance than (l), (2), and (3) but equal to each other, are:

(4) The qualifications and availability of the principal investigator and other key research personnel;

(5) The adequacy of current or planned facilities and equipment to accomplish the research objectives;

(6) The impact of interactions with other organizations engaged in related research and development, in particular DoD laboratories, industry, and other organizations that perform research and development for defense applications; and

(7) The realism and reasonableness of cost. (Cost sharing is not a factor in the evaluation.)

C. Review and Selection Process-Proposals will undergo a multi-stage evaluation procedure. First, proposals will be reviewed by a team of government technical experts using the stated criteria. Findings of the evaluation team will be forwarded to senior DoD officials for final funding recommendation for an award.

D. Certifications-All awards require certifications of compliance with national policy requirements. Statutes and government wide regulations require some certifications to be submitted at the time of proposal submission rather than at the time of award. Proposers by signing and submitting a proposal and the required cover, Appendix A, are providing: the certification at Appendix A to 32 CFR Part 25 regarding debarment, suspension, and other matters; the certification at Appendix C to 32 CFR Part 25 regarding drug-free workplace; and the certification at Appendix A to 32 CFR Part 28 regarding lobbying. Full text of these certifications may be found at: http://www.onr.navy.mil/02/notice.htm.

(This information can also be obtained by accessing the Proposal Information Package (PIP) at http://www.onr.navy.mil/auto-ops/IA/instruction.asp.)

E. Late Proposals-Any proposal arriving at the designated Government office after the above deadline is "late" and will not be considered for an award, except for the following:

(a) There is acceptable evidence that, although it was not received in the office stated in the announcement, the proposal was delivered to the designated agency by the deadline; or

(b) The proposal was sent, to the address specified for the designated agency, by U.S. Postal Service Express Mail three or more business days prior to the date specified for the receipt of the proposals. The term "business days" excludes weekends and U.S. federal holidays.

In case the operation of the designated Government office is interrupted and the office is unable to receive the proposal, the deadline is extended to the same time of the first day thereafter when the office is in operation.

Please note that proposals delivered by commercial carriers are considered "hand carried" and that no exceptions can be made to allow such proposals to be considered if, for any reason, they are received after the deadline. Proposers are advised that some proposals responding to past announcements that were sent via commercial carriers were delayed during shipment and arrived after the deadlines, typically by one or two days. To decrease the probability that proposals delivered by commercial carriers will arrive after the deadline and thus be ineligible to compete, proposers are encouraged to schedule delivery to occur before the deadline date.

F. Award Notices – Principal Investigators will receive a notice, by letter or e-mail, about 14 February 2003 reporting the outcome of the review process. For those proposals being recommended for an award, the notification should not be regarded as an authorization to commit or expend funds (except at the recipient's own risk, to the extent that the recipient allows charging to awards of 90 days pre-award costs). Negotiations may result in funding levels that are less than proposed. Only an award document signed by a Government Grants Officer will bind the Government.

G. Additional Information. Consistent with the goals of the University Research Initiative, URI funds awarded through this MURI competition will remain vested with the eligible universities participating in the proposed research. Title to equipment purchased under this program will be vested with the university without further obligation to the government. ONR's terms and conditions for grants are available at http://www.onr.navy.mil/02/terms.htm. Similar terms and conditions can be found at the websites of the other agencies.

H. Reporting-Financial Report using SF-269 (or SF-272) is required by Part 32 of the DoD Grant and Agreement Regulations (32 CFR part 32).

I. **Specific Topics** - Detailed descriptions of the FY03 MURI topics.

FY03 MURI topic #1
Submit white papers and proposals to the Army Research Office

Minimal Organotypic Cell System

Background: Evidence is accumulating rapidly that a number of innovative routes exist for establishing sources of pluripotential human cells that may grow into almost any kind of fully differentiated cell type. Some progenitor cell types are not terminally differentiated. These may be induced to differentiate and grow, with appropriate manipulation of the cell environment, as mature cell lineages representative of, and functioning like, those found in adult tissues of various phenotypes. Likewise, there exists exceptional promise in applying the rapid advances being made in physical and engineering sciences to modeling, design and construction of hybrid "natural", i.e., whole cell, systems incorporating truly functional and structural connectivities between biological and non-biological system elements. With appropriate multi-disciplinary research into biological generation and physico-chemical support, such a functional collection of cells exhibiting tissue-like behavior would provide groundbreaking capabilities for a tailorable platform or organizing template for use in Army/DoD areas as diverse as detection for biological defense and counter-terrorism , wound healing and tissue repair, bioprocessing/manufacturing, revolutionary individualized soldier communication, and soldier performance. This area of bioengineering sciences research is distinguished by unprecedented recent conceptual and technical advances and optimism. While investment by NIH has fueled advances so far in the biomedical sciences aspects, in the context of medical research, NIH is not directly addressing the organotypic minimal platform approach described here, especially as it relates to the underpinnings for engineering application relevant to Army and DoD. The area is now ripe for having the challenges and opportunities represented by these advances addressed in such a way that they might be applied in a focused manner toward Army and DoD mission relevance, and so the research sought here would seek to leverage those advances in complementary fashion.

Objective: Multidisciplinary research should emphasize the interface between biological sciences and the physical and engineering sciences and should explore enabling fundamental science underpinning the possible use of vitally supported human immortal cell line-derived "mini-human" hybrid tissue-like collections of mature, differentiated cells. These cell systems should exhibit sufficient tissue-differentiated function to mimic, at least in rudimentary form, a reproducible composite organotypic range of biochemically characteristic metabolic processes and genetic regulatory pathways, and physiologically normal stimulus-response properties. To the extent possible with any particular cell system, studies should include issues of microsystems support for viability and stability enabling self-contained organotypic behavior.

Research Concentration Areas: Fully integrated, multidisciplinary research areas might include, but certainly are not limited to (1) identification and characterization of a particular immortal cell line able to maintain stable pluripotentiality, (2) definition of the biochemical and/or biophysical microenvironmental determinants of lineage for a specific cell type as it is derived by design as "differentiation upon demand"from an immortal cell line, (3) description of the extent to which the terminally differentiated cells so obtained possess the distinguishing structural and functional properties characteristic of what the same cells would exhibit in the relevant normal human organ, (4) exploration of co-differentiation of a minimal population of specialized and supporting cells permitting reproduction, in part, of rudimentary or "primitive" synergistic cell system attributes, (5) physicochemical properties, fabrication issues, and engineering parameters for optimally permissive surface interactions for appropriate interface composition and configurations for development of self-contained hybrid bio-abio structural elements, (6) diffusional and other limitations for microcirculatory system, with microfluidics systems engineering for such circulatory support and control of chemical milieu, (7) functionalization of system sub-elements for applications considerations.

Impact: Because of the exceptional complexity of metabolic, genetic, signal transduction and other highly integrated subcellular structural elements and regulatory pathways functioning in intact mammalian tissue, it is unlikely that its extraordinarily powerful self-healing synthetic properties and intra- and inter-cellular control and communication processes can be exploited fully for many systems applications without using the whole cells themselves, complete with their uniquely evolved structural and functional properties intact. Research here will not only further enhance the fundamental science enabling a crucially needed understanding of organotypic cell systems, but also provide the technical underpinnings for engineering application of such knowledge. It will introduce revolutionary capabilities for the Army and DoD in a number of application areas such as chemical and biological defense and counter-terrorism, soldier health and performance, and entirely new concepts for interfacing functioning biological (whole cell) systems to engineered systems. These might include (1) implantable human-compatible engineered tissue hybrids for production and delivery of physiologically relevant substances, (2) *ex vivo* "canary" cell system response indicators of the presence of chemical or biological threats, (3) restorative tissue elements for bio-regenerative processes or "bionic" assist devices, (4) genetically tailorable "human" models for toxicogenomic screening and novel therapeutic strategies, (5) cell bioreactor systems for manufacturing process line monitoring, (6) revolutionary intercellular, or other functional device interconnect possibilities, (7) controlled nucleation and growth of materials-by-design composite structures.

Research Topic Chief: Dr. Robert J. Campbell, ARO, 919-549-4230, campbell@aro.arl.army.mil

FY03 MURI topic #2
Submit white papers and proposals to the Army Research Office

SELF-ASSEMBLING MULTIFUNCTIONAL CERAMIC COMPOSITES

Background: Advances in several critical research fields now provide a unique opportunity to self-assemble ceramic colloids of multiple compositions into controlled two- or three- dimensional networks for shape forming of functional ceramics. This processing strategy will enable a new class of multifunctional ceramic materials in which new capabilities (optical, actuation, electrical, permeative, etc.) can be directly and precisely integrated into commercial-grade ceramics, offering superb application to DoD needs in the areas of optics, smart materials, electronics, and sensors. Contrary to most commercial processes, colloidal ceramic processing allows for robust and inexpensive shape forming techniques, which have now been demonstrated to provide superior properties and reliability (including the establishment of threshold strengths) via the reduction in size and concentration of agglomerates and inclusions. Only recently has the scientific understanding been advanced to the point where self-assembly of ceramic powders in suspension is a realistic possibility, most notably via the adsorption of molecules in order to produce steric stabilization and depletion flocculation, and via the segregation of charged particles. Although the specificity and activity of molecular binding to ceramic surfaces has historically been a significant barrier, molecular adsorption and grafting has been demonstrated and characterized for an ever-increasing number of ceramic surfaces, including: alumina, silica, titania, zirconia, silicon nitride, silicon carbide, and barium titanate. Similarly, investigation of the *in vivo* acceptance of implants (which is heavily governed by blood protein adsorption) is beginning to develop an understanding of the dynamics of protein adsorption onto ceramic surfaces, and peptides have recently been evolved to bind and even assemble semiconductor surfaces with extraordinary specificity. Finally, synthetic chemistry offers several methods for designing molecules with the precision necessary to facilitate self-assembly of suspended ceramic particles, including synthetic block co-peptides that have successfully been designed to closely mimic natural protein activities. This research effort seeks to extend each of these advances, together with the science of molecular self-assembly, in order to develop robust controlled assembly of ceramic colloids for the shape forming of novel multifunctional ceramics.

Objective: This research program will develop a multidisciplinary research consortium to simulate, design, characterize, and synthesize multifunctional ceramic materials via self-assembly of ceramic colloids. The effort includes the development of robust controlled assembly strategies for designing particle networks, and the engineering of optimized functional ceramics with these strategies. Substantial feedback between the processing and property characterization efforts is required.

Research Concentration Areas: An integrated multi-disciplinary approach combining research expertise in surfactant and polymer synthesis, ceramic processing, surface chemistry, thermodynamics, molecular simulation, and biomimetics is desired. The proposal should identify specific target areas of impact that complement the development of self-assembly strategies for ceramic colloids, and present an integrated plan to transfer the research results to these target areas. Specific research areas of interest include: (1) establishment of molecular adsorption and grafting strategies for optimized and tunable binding of ceramic surfaces to enable interparticle separation control; (2) molecular simulations for predicting adsorption and grafting of synthetic molecules onto ceramic surfaces and the tail interactions of these molecules; (3) design and synthesis of molecules with engineered specificity and activity for self-assembly; (4) elucidation of the physical processes governing protein adsorption and binding in bioceramic materials; (5) engineering of colloidal ceramic assemblies via peptide-controlled synthesis; (6) characterization, computational simulation, and design of self-assembly strategies for organizing powders of multiple compositions into specific particle architectures; and (7) engineering new functional ceramics using state-of-the-art ceramics colloidal processing techniques.

Impact: This program is expected to have a revolutionary impact on the field of ceramics, enabling unprecedented processing control in order to provide novel multifunctional materials for a wide variety of DoD-relevant applications including optics, smart materials, electronics, sensors, and membranes.

Research Topic Chief: Dr. David M. Stepp, ARO, (919) 549-4329, steppd@aro.arl.army.mil

FY03 MURI topic #3
Submit white papers and proposals to the Army Research Office

Fundamental Theoretical/Experimental Molecular Science Underpinning Fuel Cell Systems

Background: Although fuel cells have been extensively investigated in recent years, there is at present no unifying theory of these systems that enables practical fuel cells in military situations. This is because fuel cells are complex structures that involve chemical, electrochemical, and physical phenomena over a wide range of length scales: nanoscale (e.g., electrocatalyst), microscopic scale (e.g., three-phase interfacial region of reactant + electrolyte + electronic conductor), mesoscale (e.g., membrane-electrode assembly), and macroscale (e.g., flow fields). Current development of fuel cell systems is impeded by lack of integrated theoretical science and computational tools to provide fundamental understanding of processes and the required material properties of various fuel cell components. This is particularly true of fuel cell systems that use complex, heteroatom-containing hydrocarbon fuels of the sort that are of primary interest to the DoD. The findings from a 2001 multidisciplinary DoD workshop (www.aro.army.mil/chemb/finals/workshop/workshop.htm) note that three components now drive the development of chemical-process based systems: (i) experiments, (ii) chemical concepts, and (iii) simulations. Recent work has set initial steps for a first-principles-based, theory-guided selection of new electrode and electrolyte materials and structures, the fundamental understanding of catalytic and electrocatalytic mechanisms, and the molecular design of heterogeneous catalysts and electrocatalysts. Computational electrochemistry is, however, nascent and its utility is only slightly developed. This MURI seeks to integrate the aforementioned areas of research and the many supporting disciplines into an effective tool for theoretical evaluation of concepts, materials, and subsystems supporting fuel cell power generation. The theoretical efforts must be complemented (within the MURI program) by an experimental element that validates theory as well as synthesizes and characterizes the new advanced materials and structures that result.

Objectives: Develop an integrated first-principles theoretical/experimental approach to enable the conception, synthesis, fabrication, development, and understanding of advanced materials and structures for PEMFCs and SOFCs and the associated hydrocarbon fuel reformers in an overall fuel cell system. The multidisciplinary team assembled to address these issues would include chemists, physicists, materials scientists, and chemical/electrochemical engineers.

Research Concentration Areas: Areas of interest include, but are not limited, to the following. (1) Development of theory- and computation-based coupling methods that link short-length/short-time processes (sub-nanometer and nanoseconds) with long-distance/long-time events (cm and seconds). (2) Refinement of theoretical methods such as: (i) functionals to describe potential energy surfaces in chemical and electrochemical bond breaking/making, particularly with highly correlated systems such as those involving transition metals commonly used as fuel processing catalysts or electrocatalysts; (ii) combined electronic-structure/molecular-dynamic theory to provide new accurate information of chemical/electrochemical reactions in realistic catalyst/support/electrolyte/reactant/product environments; and, (iii) local correlation methods and psuedopotential-based *ab initio* approaches. (3) Development and enhancement of first-principles based theories for surface-science methods commonly applied to catalysts/electrocatalysts such as STM, EXAFS, XANES, XPS, NMR, spectroscopic and scanning probe techniques, and neutron scattering. (4) Development of the understanding of state-of-art catalytic/electrocatalytic processes through a computational chemistry/electrochemistry approach as a basis for a complementary experimental program to propose, prepare, and characterize new catalytic and electrocatalytic materials.

Impact: Typical design issues and material choices associated with fuel cells are characterized not only by the usual intricacies of the interfacial region at which a charge-transfer reaction occurs, but also by the complex multi-functional character of the materials used as electrodes and electrolytes. In addition, hydrocarbon fuels available to the military typically contain sulfur and nitrogen, which add complexity to fuel processing and/or direct electrochemical oxidation. Advances in computational chemistry, computational methods, and computer hardware, however, are making it practical to consider first-principle-based predictions of the important processes and materials of fuel cell systems. The approach envisioned under this MURI topic is a paradigm shift from the heuristic methods presently employed in discovering and developing materials and structures for PEMFCs and SOFCs. The MURI activities will complement other DoD-funded power-related programs by taking advantage of improvements in theory and computational advances to do molecular scale modeling of the most complicated interfaces, processes and materials in fuel cell systems at a far more detailed level than has been done before.

Research Topic Chief: Dr. Richard Paur, ARO, 919-549-4208, paur@aro.arl.army.mil

FY03 MURI topic #4
Submit white papers and proposals to the Office of Naval Research

Integrated Artificial Muscle, High-Lift Bio-Hydrodynamics and Neuro-Control for Biorobotic Autonomous Undersea Vehicles

Background: In the past, engineers drew inspiration from physics to build new machines. The approach has matured so much that submarines and unmanned undersea vehicles (UUV) largely look and perform the same as they have in the past. This incrementalism can be broken if we realize that Biology has supplanted physics as the fountain of inspiration. To clarify, observe that steady state hydrodynamics, on which submarines and aircraft are designed, do not explain the hovering or rapid turning of coral reef fish or the high lift of fruit fly. In animal swimming and flying, unsteady hydrodynamics is the norm. Engineers are yet to build vehicles based on these newly uncovered unsteady high-lift principles. But then we can hardly use any conventional motor drive train, however reliable they might be, to produce the 3D motions of these lifting surfaces. So, we need anisotropic artificial muscles (AM) that match or exceed the properties of mammalian muscles. This can be rationally developed via molecular design. Thus, if we are to spark the next revolution in underwater or aerial platform generic capability in low-speed maneuvering, silencing, signature, power or weight, we need to integrate the science and technology of high-lift bio-hydrodynamics and artificial muscle. It immediately follows that the combination becomes eminently amenable to neuro-based control, truly allowing a vehicle to be authoritatively autonomous in its underwater or aerial surrounding or an underwater weapon to have unprecedented stealth.

Objective: The program will develop and integrate the science of AM, Bio-Hydrodynamics and Neuro-Control on a common foundation for the development of biological aquatic pectoral fin inspired 3D dynamic lifting foils that endow unprecedented low-speed precision maneuvering ability, stealth and life-span to AUVs (Autonomous Undersea Vehicles) and weapons. The objective is also the supplanting of drive trains for actuation of control and thrust foils by AM. Benchmarks will be provided from a planned conceptual design, of a Biorobotic AUV with advanced dolphin-like mobility.

Research Concentration Areas: Areas of interest include, but are not limited to, the following. (1) Understanding of fish pectoral fin muscle physiology and their neuro-control mechanism (example: box fish). (2) The molecular design of conducting electro-active polymers and other competitive artificial muscles to match or exceed the properties of mammalian muscles. Optimization of conflicting material properties for use in Underwater Vehicles of which benchmarks would be provided. The production and basic engineering of such muscles. Required material properties are: compact small volume actuator with optimum combination across entire matrix of strain, stress, power, efficiency and weight; use as actuator, power source or sensor; amenability to neural net; and overall, closer to biology. (3) The engineering implementation of the anisotropic physiology and neuro-control of the pectoral fins of fish via AM and coding on a microprocessor, or such means of control. (4) Scaled study of high-lift mechanism of flexible 3D pectoral fins of AUV-appropriate aquatic animals undergoing heave, pitch and twist and their Reynolds scaling laws. (5) Ocean engineering extension of high lift mechanism to high Reynolds numbers in rigid cylindrical hulls. (6) Finally, the system-based integration of the distilled science of the three disciplines into a pectoral fin like programmable light, flexible and multi-degree of freedom underwater hovering and maneuvering control surface for rigid hull forms. Mechanism based simulation, analytical modeling, novel experimentation and design are expected to be undertaken.

Impact: The three services are developing unmanned vehicles for both surveillance and combat. While endurance is the early focus, mission success depends on *low-speed maneuverability*. Swimming animals excel in that. Consequently, if successful, the actuators from this MURI would impact several DOD Programs. In the littoral zone, Navy would be impacted in the areas of low-speed maneuverability in the smaller platforms of AUV, CM, Gliders in the short to medium time scale, and in the stealth of weapons in the longer time scale. (1) AUVs, instead of making high resolution 1D linear scans for mine detection would be encircling and diagnosing mines 'a la dolphins', and thereby improve sensor competence. Energy and bandwidth of AUVs would be impacted. (2) AM would make long duration underwater gliders maneuverable. Integrated AM, high-lift & their neuro-control would make the submarine-launched Counter Measures mobile and their herding feasible. (3) The elimination of drive trains preventing hull vibration would lead to unprecedented platform quieting.

Research Topic Chief: Dr. Promode R. Bandyopadhyay, ONR 703-696-3163, bandyop@onr.navy.mil

FY03 MURI topic #5
Submit white papers and proposals to the Office of Naval Research

Direct Thermal to Electric Energy Conversion

Background: A variety of technologies currently exist for converting thermal energy sources to electricity. Examples include thermionic (TI), thermoelectric (TE) and thermophotovoltaic (TPV) energy conversion. Typical thermionic devices require high temperature heat sources for operation and uses have generally been limited to high power space applications. While there have been some recent advances in thermoelectric and thermophotovoltaic materials and devices, it is still challenging to obtain high efficiency in the lower temperature regimes. Furthermore, while Carnot efficiencies drop as the temperature differences become smaller, TE, TPV and TI efficiencies are far from the ideal Carnot. The low efficiencies are the result of a combination of factors associated with chemical composition of materials, physics of transport of electrons and phonons, and the fabrication of devices/modules and their integration into systems. Opportunities exist to develop new materials and conversion devices by exploitation of engineered nano- and microstructures.

Objective: The program seeks to develop a strong science base for the eventual development of modules and systems capable of efficiently converting thermal energy into electrical power at relatively low temperatures (i.e. 300 - 650°C). By coupling expertise in the chemistry, physics, materials and engineering communities, it is envisioned that new materials can be developed and engineered into unique structures, devices and modules to allow for efficient, low temperature energy converters with relatively high specific powers.

Research Concentration Areas: New concepts and ideas are sought which will offer the potential to overcome scientific hurdles of current thermal energy conversion technologies are desired. A broad based science program including, but not limited to, one or more of the following technical areas is envisioned: thermoelectric, thermionics and thermophotovoltaics. Examples of some interests include: 1) understanding and independently controlling phonon and electron transport in novel chemical systems and engineered structures 2) synthesis of new compositions of matter leading to enhanced materials properties 3) modeling of cooperative or parasitic effects associated with scaling 4) efficient transfer of phonons and photons from thermal sources to converters 5) effects of nanoscale structures/assemblies on mesoscopic properties (i.e. work function, Seebeck coefficient, thermal conductivity) 6) novel hybrid approaches to couple various conversion technologies (i.e. TE plus TPV).

Impact: The ability to efficiently convert thermal to electrical energy will have significant impact on a variety of DoD systems from undersea to space based applications. Advances in science on different fronts can impact a variety of applications: Development of stable low work function materials can yield new thermionic devices that operate at low temperatures (300-650°C), new bulk thermoelectric materials can facilitate manufacture of modules and systems, and innovative coupling of energy transfer methods and identification of new phenomena (heat pipes, optical fibers, close-spaced systems, etc.) can result in improved energy efficiency. It is envisioned that these technologies could be used from systems ranging from watts to megawatts. New solid state thermal conversion technologies could simplify secondary conversion systems used by the DoD and could provide power for a new generation of wireless remote sensors. Ultimately these conversion devices will lead to warfighting capabilities in enhanced stealth, increased payload volume, reduced logistics, and reduced manning via automation.

Research Topic Chief: Dr. John Pazik, ONR 696-4404, pazikj@onr.navy.mil

FY03 MURI topic #6
Submit white papers and proposals to the Office of Naval Research

Image Processing Sensors for Autonomous Vehicles, Robotics and Remote Sensing

Background: Imaging sensors currently are used to capture images from visible, infrared, and sound or sonar signals, such as Focal Plane Arrays. These sensors are arrays of individual pixels, whose output is addressed individually for transmission to the image processing computer. These sensor arrays are separate from the processing computer. The analog data must be digitized by ADCs before processing digitally. All processing functions are determined by large software programs, which are maintained within the computer. In spite of continually increasing digital processor speeds, the overall image processing speed, or frame rate, is slow. This severely limits the operational capabilities of any intelligent sensor system. In addition, the required computer resources are relatively large and consume significant amounts of electrical power, which preclude the use of such systems on many types of military vehicles. Further, complex operations, such as hyper-spectral and other image fusion processes, require even greater resources. Imaging systems on remote platforms require enormous bandwidth capabilities for transmission of video information, so that, any new capability for on-site image processing would dramatically enhance real-time response of such platforms. Biological systems may provide design answers to the aforementioned image processing problems. For example, recent work (Werblin, 2001) shows that the 5-layer neural network comprising the retina is capable of extracting 12 distinct images based on edge-detection, movement, spectral sensitivity, etc. before this information is passed to more complex "cognitive" processing in the cortex. The last 10 years have witnessed a dramatic increase in understanding of biological sensory processing that can now serve interesting functions (e.g. artificial cochlea).

Objective: Image processing functions based on those observed in vertebrate and invertebrate retinae will be explored and adapted to an electronics technology. As an intermediate step, insight derived from biological information processing will be used in computer architecture advances. Eventually, hardware advances will be made by utilizing hybrid analog/digital computation, where large digital bit accuracy is not required. Hybrid circuits will be designed using available technologies. Advanced algorithms will be developed which allow for greatly reduced requirements on computer resources. Biologically inspired algorithms will implement operations such as Automatic Target Recognition, targeting and tracking, perimeter and space surveillance, and autonomous robotics. Focal Plane Arrays and artificial retina sensors will be integrated directly on the chip level processor. We are looking to implement biologically inspired parallel architectures for image processing without dedicated digital systems.

Research Concentration Areas: Areas of interest include, but are not limited to the following: (1) investigate information processing of vertebrate and invertebrate retinae; (2) develop Cellular Neural Network algorithms for hyper-spectral and image fusion operations; (3) design hybrid analog/digital circuits to implement image processing functions; (4) integrate focal plane array sensors with computer processor; (5) developing programming tools for systems requirements; (6) understand the biological algorithms underlying sensor fusion, both within and between sensory modalities.

Impact: Very high frame rate image processing with complex processing algorithms combined in a small electronics package will provide dramatic performance enhancements in many military platforms. In addition, on-site, real-time image processing will greatly reduce communication bandwidth requirements adding to overall response rates. Some of the possible platforms include: helmet mounted or rifle mounted sensors for visible or IR imaging; targeting and tracking sensors for missile guidance; high speed automatic target recognition; vision systems for adaptive response in robots; imaging systems for Micro Air Vehicles; satellite surveillance systems; perimeter systems; low light vision enhancement systems.

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FY03 MURI topic #7
Submit white papers and proposals to the Air Force Office of Scientific Research

Hybrid Inferencing from Fused Information

Background: Effective Network Centric Warfare depends on high quality awareness. In turn, proper understanding of a situation relies on detecting militarily significant elements within large geographic areas and determining the often multi-dimensional relationships among them. Information fusion improves the quality of awareness and contributes to speed of command through the mining of knowledge bases that incorporate disparate information sources. The ability to deal with these disparate sources is becoming more important as the situations the U.S. military is being called upon to face are increasingly unfamiliar. Knowledge-base technologies are increasingly successful in representing the current state of complex environments from which inferences can be drawn about current threats and possible future threats. The volume of information available, however, is expanding more rapidly than the ability to form decisions based on it, using either human experts or existing decision support tools.

Objective: The Hybrid Inferencing from Fused Information (HIFI) program discovers tools and approaches for extracting models used by experts and expressing those models in algorithmic or heuristic form. The long-term goal is to replicate expertise through automation and to create and maintain flexible ontologies shared between human and automated systems. Approaches to hybrid inferencing, shared between human and machine, are required for decision-making technologies that best combine computing speed and accuracy with human flexibility and creativity. The focus of this program is generating intelligent decisions from previously fused information, rather than the processes of information fusion. Further, the focus is on high levels of inferencing involving volumes of information (strategic and operational levels) rather on levels where performance is limited by available data or its effective aggregation and fusion.

Research Concentration Areas: Areas of interest include, but are not limited to: (1) cognitive analysis of behavioral streams provided by human expert interaction with large knowledge bases, for example, during data mining activities and the construction of mental models of unfamiliar situations; (2) behavior of heterogeneous teams and their ability to generate quality awareness and to share mental models with team participants; (3) impact of collaborative behaviors on the level of awareness achieved and the ability to share it; (4) self synchronizing behaviors (decisions, plans, actions) based upon shared awareness; (5) knowledge- and data-engineering approaches to model creation, and model-based inferencing in support of flexible ontologies; (6) mathematical approaches to detecting correlated elements and activities and matching them with existing models; (7) operations research to develop approaches to determining what new information might best resolve competition between active interpretations; and (8) creation of quantitative measures of effectiveness for comparing various approaches to making sense of disparate information sources in the context of both familiar and unfamiliar situations.

Impact: The HIFI program provides new approaches to use of large volumes of fused information for sensemaking. The program supports the effective use of large and increasing volumes of data that cannot be processed by human experts alone through the discovery of hybrid approaches. The program seeks flexible accurate functional area models required for command and control, intelligence, effects-based operations, and battle damage assessment.

Research Topic Chief: Dr. John F. Tangney, AFOSR, 703-696-6563, John.Tangney@afosr.af.mil

FY03 MURI topic #8
Submit white papers and proposals to the Air Force Office of Scientific Research

Biologically Enabled Synthesis of Ceramic Microdevices

Background: Microdevice fabrication has been largely limited to silicon photolithography techniques developed for the microelectronics industry; however, such 2-D processing is not well suited for the low-cost mass production of complex, 3-D micro-components. Importantly, for many of the DoD applications, the operating environment of the microdevice will be both chemically and environmentally aggressive -- conditions which silicon based devices are not well suited. Novel surface treatments and coatings ***could*** be used to improve the performance of existing materials but the high stresses associated with the small scale of the internal structure and the probable need for heat dissipation, are ideal applications for monolithic, high-performance ceramics. Recent research on bio-templating has illustrated that complex silica based structures can be chemically converted to a structural ceramic while maintaining the complex 3-D internal architecture.
Nano, micro, and larger scale materials have recently been developed which take advantage of the many available biomolecules and bio-organisms, including proteins, poly nucleic acids (both natural and synthetic), lipids, cells, and viruses that can be used as synthetic directors in materials manufacturing. One larger scale example of the bio-organism as a manufacturer was the production of dragline silk recombinant proteins from mammalian cells used to produce a material similar to dragline silk.[1] Biologically enabled synthesis of functional materials offers several unique opportunities to the design of new ceramics including, the ability to direct structure due to customizable molecular recognition properties and the opportunity to serve as bio-templates for constructing *functional* architectures. Recent research on bio-templating[2] has illustrated that complex silica based bio-structure derived from diatoms can be chemically converted to a structural ceramic while maintaining the complex 3-D internal architecture.

Objective: This MURI program will focus on the investigation of biomolecules and bio-organisms as synthetic tools for fabricating functional ceramic microdevices. The successful proposal will include a research team capable of genetically manipulating biomolecules and bio-organisms to synthesize new template materials that can be subsequently chemically converted into monolithic ceramics or ceramic composites. A successful approach should include the full evaluation of the structural, optical, electrical, magnetic, and/or catalytic properties of the resultant ceramic. Characterization should be done sufficiently enough to garner an understanding of both the genetic manipulation and the synthetic conversion process of the ceramic produced.

Research Concentration Areas: Areas of interest include, but are not limited to, the following: (1) the use of microbes as synthetic machinery for building nano- and microstructures of controlled size, shape, and composition is highly desirable; (2) need to address how these biological structures can be interfaced or converted into functional ceramics on the bulk, micro, and nano-scales to prepare functional architectures; (3) in addition to conventional synthetic tools for fabricating ordered architectures via bio-templating, the successful proposal should include novel and state-of-the-art methods for controlling the 3-D shape of the biological template through genetic manipulation; (4) the proposal should include the development of synthetic design strategies to allow for multi-component or graded functional materials of the resultant ceramic microdevice; (5) the scale-up of both the biomolecule or bio-organism and the resultant new ceramic microdevice should be part on any research plan; (6) potential applications of the ceramic should be addressed and demonstrated. Examples of potential functional materials include, but are not limited to ZrO_2 for optics, TiO_2 for sensors, $MgSiO_4$ or Al_2O_3 for structural applications and (7) the successful proposal will address how theory can guide the experimental approach and selection of target materials for the most synergistic combination of functions.

The unique aspect of the solicited research is its emphasis on the ability of bio-organisms to control the synthesis of 3-D shapes in a semiautonomous way and the conversion of these novel architectures into a ceramic material tolerant of aggressive environments. Preference will be given to proposals that clearly identify target areas of impact and present a plan to transition research results to these applications.

Impact: This program has the potential of greatly impacting the design and synthesis of functional ceramic microdevices. The ultimate realization of biologically enabled synthesis to produce complex, three-dimensional, ceramic materials would significantly accelerate the incorporation of new ceramics into future DoD and commercial applications, including i) medicine (e.g., for targeted drug delivery, *in vitro* sensing, microsurgery), ii) telecommunications (e.g., micro-optical devices, micro-actuators), iii) transportation (e.g., microcomponents for automobile and jet engines), and iv) power generation and storage devices.

Research Topic POCs:
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Dr. Hugh De Long, AFOSR/NL, 703-696-7722, hugh.delong@afosr.af.mil

FY03 MURI topic #9
Submit white papers and proposals to the Air Force Office of Scientific Research

Active-Vision for Control of Agile Maneuvering Aerial Vehicles in Complex 3-D Environments

Background: Recent advances in imaging technologies offer the possibility for deployment of aerial vehicles and munitions with autonomous sensing and control, that, individually or collectively, are capable of detecting, locating, classifying and prosecuting collections of intelligent, mobile, defended targets. Such aerial vehicles must be capable of operating effectively in a clandestine/covert manner and in close proximity to structures and/or terrain. Vision based sensors (e.g., 2-D or 3-D imagery from SAR, LADAR, FLIR, etc.) will play a major role for improved target recognition/tracking, obstacle/hazard avoidance, navigation, control, and cooperation.

Current imaging guidance systems process imagery to detect, classify, and discriminate targets, then use conventional intercept algorithms to attack the target. Using inspiration from biological vision systems, a new class of active vision based vehicle guidance systems could be developed to give aerial vehicles the ability to make real-time context appropriate responses based upon object size, orientation and the overall visual flow field. This will require multidisciplinary research in image processing methods, state estimation, guidance and flight control, and swarming and cooperative strategies applicable to aerial vehicles. The result will be enabling technologies for formation control, agile and coordinated maneuvering through congested air spaces, and swarming attack against dispersed targets.

Control theory plays a central role in the design of active vision systems for air vehicles. In particular, nonlinear adaptive and robust control are essential tools in understanding uncertainty in both machine and biological vision. Such issues as dynamic coupling among sensor signal processing, image processing, guidance estimation, and aerodynamic control become performance limiting when one uses a visual sensor in an uncertain environment and attempts to feed back the image information. A question of paramount importance is how feedback may improve the information provided by various vision modalities in an uncertain, congested, potentially adversarial environment. The particular challenge for air vehicles is that because they move in a 3-D environment, the dominant motion in the imagery is imparted by motion of the vehicle. Adaptive and robust control in conjunction with multiscale methods from signal and image processing, as well as shape and object recognition theory from computer vision are relevant.

Objective: To develop the fundamental theory, algorithms and tools: i) for autonomous active vision systems to provide agile aerial vehicles with real-time spatial awareness of complex environments; ii) to utilize sensory data from active vision systems for guidance and control of aerial vehicles in complex environments. To understand/characterize the limitations of active vision for guidance and control of autonomous agile vehicles in highly uncertain scenarios; to provide algorithms that can augment vision with other sensory information (e.g., acoustic, echolocation) for use in such situations.

Research Concentration Areas: Areas of interest include but are not limited to: 1) vision based obstacle avoidance, 2) novel mathematical methods for vision, control, and tracking including those from partial differential equations, statistics, and geometry, 3) strategies to utilize visual information for improved single and multiple aerial vehicle state estimation, 4) related target recognition and tracking, optical flow, path planning, guidance, navigation, and flight control methods, including robust adaptive control, 5) multiscale image and signal processing, 6) biologically inspired machine vision, sensor data fusion and processing, 7) biologically inspired approaches to vision-based guidance and control in complex environments, 8) shape and object recognition methodologies applicable to aerial vehicles. The sound and scalable theories and algorithms developed in the project will be demonstrated in flying testbed.

Impact: Autonomous vision systems are critical enabling technologies for development of guidance and control systems that will provide the capability for tactical munitions and UAVs to operate within uncertain, congested, and adversarial environments. Utilization of vision-based sensory information will provide the critical situational awareness that is required to avoid fixed or moving obstacles, find hidden or camouflaged targets, discriminate targets from non-targets, and accomplish this in real-time while performing the agile maneuvering required for close-to ground flight operation. The fundamental theory and understanding provided by this topic will impact the existing MURI topics in cooperative control of autonomous systems by providing cooperative flight strategies that utilize vision, facilitate multiple vehicle classification of targets, and multi-vehicle task coordination.

Research Topic Chief: Dr. Belinda King, AFOSR, 703-696-8409, belinda.king@afosr.af.mil

DFY03 MURI topic #10
Submit white papers and proposals to Defense Advanced Research Projects Agency

Direct Nanoscale Conversion of Bio-Molecular Signals into Electronic Information

Background: Biological systems exhibit remarkable sensitivity, selectivity and efficiency that could be exploited in engineering systems should appropriate interfaces become available. Biological systems have well defined sensing units, signal processing units and actuation sub-systems that determine responses to specific stimuli. While significant effort has gone into understanding the sensing systems of biology (e.g., receptor and transmembrane proteins), the intra-cellular signal processing system is still the subject of many ongoing research efforts. The objective of this research is to develop hybrid bio-molecular systems that use biological units (e.g., proteins) for performing the sensing function but use silicon circuitry to accomplish the signal processing. Innovative ideas are needed for the development of interfaces that accomplish this objective. If successful, this research will lay the foundation for advanced 'biology-to-digital' converter systems that enable direct, real-time conversion of biological signals into digital information. It is anticipated that these interfaces could also be used to electronically control the activity of bio-molecules in a programmable/reconfigurable manner, i.e., a 'digital-to-biology' converter.

Ongoing research in nanotechnology is starting to demonstrate controlled fabrication of high quality nanostructures (nanoparticles, nanotubes, nanopores, etc.) that are capable of interacting with biology at the molecular scale. Significant recent accomplishments in biology and surface chemistry have also demonstrated controlled self-assembly of engineered molecular structures into well defined patterns on surfaces. It is anticipated that these developments will lead to new kinds of bio-electronic interface technologies extendible to nanoscale array platforms that enable large scale integration and parallelization.

Objective: This topic seeks innovative research into the development and demonstration of novel nanoscale interface technologies that enable the direct, real-time conversion of bio-molecular signals into digital information while also facilitating programmable control and tuning (through silicon circuitry) of the bio-molecular system.

Research Concentration Areas: Areas of interest in this research may include, but are not limited to :

(i) **Signal Acquisition and Transduction** : Investigate the nature of signals that need to be extracted from bio-molecular systems and the information content in these signals. Explore engineering of bio-molecular systems to provide specific signals of interest. Study and quantify acquisition, filtering and amplification of the signal by the bio-molecular system.

(ii) **Electronic Addressability at the Molecular Scale :** Investigate novel technologies to enable single molecule addressability at the nanoscale for high SNR (Signal-to-Noise Ratio) transduction of the signals for further processing in silicon. Develop novel interface technologies to ultimately convert these signals into real-time electronic information. Demonstrate real-time, programmable control of bio-molecular performance through these interfaces. Demonstrate scale-up into nanoscale array platforms with large scale integration.

(iii) **Demonstration of Devices and Arrays** : Develop novel materials technologies to ensure robust and reliable operation of array platforms. Demonstrate operation and controllability of devices and systems and quantify performance metrics for the device/system (sensitivity, selectivity, efficiency and power consumption).

Preference will be given to proposals that address these issues in the context of potential areas of impact.

Impact and Relevance : The availability of these interfaces will result in ‘smart’ bio-molecular assemblies with new functionalities such as direct molecular readers, ‘artificial’ cell systems, nanoscale power generation systems, nano-reactors, etc. This effort will form the groundwork for the development of a new generation of nano-devices/systems that will have a revolutionary impact on almost every discipline, especially health monitoring, wirelessly addressed implantable devices, explosives/mines detection, energy conversion, bio-catalysis, bio-engineered materials, molecular computing/information processing systems.

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FY03 MURI topic #11
Submit white papers and proposals to the Director of Basic Research

Synthesis of Long-Chained Sequence-Controlled Heteropolymers

Background: Modern polymer science since the 1930s has produced a wide range of plastics that are used in a wide variety of consumer products and in nearly every industry. Synthetic polymers of all types can be produced today with varying strength, stiffness, density, and heat resistance. Polymers can be used as structural materials as well as functional material such as conducting polymers in electronics and optoelectronics. While most of today's polymers are macromolecules formed by long chains of monomers, a long sought after goal in polymer science is to be able to synthesize long chains of heteropolymers with a well controlled and repetitive sequence. Such heteropolymers offer an unprecedented opportunity for expanded understanding in polymer science to synthesize materials of unique properties, for structural and functional applications including devices for biochem sensing and electronics.

Objective: This academic initiative is to understand the science of heteropolymers to allow us to synthesize these long-chained sequence-controlled heteropolymers.

Research Concentration Areas: All proposed approaches to achieving the stated objective will be considered. The following three possible approaches are provided only as examples.

(1) Evolution of Functional Heteropolymers through Biomimetic Principles

Nature, over billions of years, has seen fit to translate novel DNA sequence information into new proteins, and then link the novel properties of these proteins to the survival of the DNA encoding them. It is now time to explore biomimetic (i.e. abiotic) approaches to heteropolymer synthesis. Biologists already perform desktop microbial evolution of biopolymers (proteins and nucleic acids). While such bioheteropolymers have many advanced features not seen in chemical polymers (such as defined sequence and length, enabling them to fold and generate binding pockets for example), the requirement for aqueous conditions during intracellular synthesis limits their DOD applications. Therefore, synthesis of heteropolymers is to be achieved through biomimetic principles that permit iterative cycles of sequence diversification, selection, and amplification that are inspired by the genetic mechanisms of Nature. Research should consider the following: (1) Identify the desirable/feasible properties of the target heteropolymer(s) and hence a set of relevant polymer backbone(s) and monomer functionalities. (2) Develop an amplifiable (presumably polymeric) encoding template containing sequence information, analogous to DNA in Nature and amenable to directed or random mutagenesis. Physical imprinting by a templated matrix is not what is sought, however; it is likely (as in Nature) that the heteropolymer will bear no structural resemblance to the encoding template. (3) Develop mechanisms for translation of the encoded sequence of the template to the growing heteropolymer and for the inter-monomer coupling chemistry. (4) Develop selection schemes appropriate to the desired properties of the evolved heteropolymer, in which each encoding template is associated (chemically or physically) with its cognate heteropolymer during the selection round. (5) Ensure that template sequences corresponding to selection "hits" are amplifiable from small copy numbers in complex libraries. Because the challenge posed by this initiative is formidable, high quality responses to any or all components of the encoded synthesis/diversification/selection/amplification cycle will be considered. In every case, however, the required convergence of biology, materials science, chemistry, and computation in this initiative means that a strong multidisciplinary team is an imperative. Point of contact: Dr. Harold Bright, ONR-342, 703-696-4054, brighth@onr.navy.mil.

(2) Chemical Routes to the Synthesis of Heteropolymers

Analogous to the biological process for sequence controlled polymers is templated synthesis in which a polymer backbone or supramolecular complex directs the monomer ordering and subsequent polymerization. Difficulties here arise from attachment and release chemistries along a macromolecular template. In theory, once a template is made with appropriate chemistries for binding, polymerization, and release, macromolecules of a specific sequence and molecular weight can repeatably be made in just a few steps from feeds of mixed monomers. In practice, these chemistries are just being worked out for short oligomeric templates. A more traditional method is sequential chemistry to build the desired heteropolymer a unit at a time. This approach can be significantly enhanced/automated by the use of microreactor or combinatorial technology. In this approach the monomers are sequentially directed to growing chains often affixed to a solid substrate. Careful design and clean, quantitative linkage chemistries are necessary to achieve the goal of sequence-controlled long-chain heteropolymers. In practice, such chemistries break down long before attainment of high molecular weight. Significant research and potentially new approaches are needed to advance synthetic approaches beyond oligomeric sequences. Researchers should identify the desirable/feasible properties of the target heteropolymer and hence a choice of relevant polymer backbone(s) and monomer functionalities for potential use in biochemical sensing, electronics, photonics or other pertinent area. An effort should be proposed centered on the synthetic chemistry but interdisciplinary with appropriate quantitative chemistry, physics, computation, and/or biology. Point of contact: Dr. J. Paul Armistead, ONR-331, 703-696-4315, armistj@onr.navy.mil

(3) Heteropolymer synthesis through direct molecular manipulation

With the advances in atomic probes and manipulators, such as Atomic Force Microscope, it is now possible to move individual atoms one at a time. Technology is available to lift the end of a long chain of polymer and place it next to the end of another chain and cause chemical bonding. Similarly, laser tweezers have been demonstrated in manipulating and directing the movement of single long molecular strands. These techniques can potentially offer a unique opportunity to control the chemical reaction at the end of a specific long molecular chain. Reaction can be induced at a targeted reaction site where one or both reactants are under direct physical control to form a specific product. Local external stimulation (such as electrical or optical signal) can be an added dimension of reaction control. This approach differs from conventional polymerizations or chemical reactions where products are formed from a pool of randomly accessed reactants. This scheme of reaction control can enable the synthesis of very long chains of heteropolymers with very specific sequential order by coupling presynthesized long chains. It can also build complex architectures on pre-patterned substrates, connecting predetermined sites with specific polymer chains. It can also lead to the assembly of complex sequences of heteromonomers such as those that would be found in a molecular electronic circuit. The heteromonomers can be from a variety of molecular electronic components (e.g. molecular wires, molecular transistors, molecular diodes). Coupling the manipulation techniques with the right type of chemistry to facilitate site attachment, selective reaction, and if necessary controlled release of the reaction products from the binding site will be one of the many challenges. Being able to control both ends of a long chain with molecular scale resolution may offer new schemes of controlling the chain reaction. This research will require interdisciplinary collaboration (physics, chemistry, engineering and/or biology). Researchers should select polymers and research targets relevant to defense interests such as in electronics, photonics, biochemical sensing or other pertinent areas. Point of Contact: Dr. Charles Y-C Lee, AFOSR/NL, 703-696-7779, charles.lee@afosr.af.mil

Impact: The ability to synthesize heteropolymers of defined sequence will create a new and broader class of materials beyond elastomers and plastics. These heteropolymers will be designer material with specific properties. For example, the biomimetic routes to polymeric materials and small molecules for both the military and civilian communities, and a synergism with design theory and molecular simulation will revolutionize the way polymers are made. Polymers of defined sequences and lengths, with the possibility of side chains, will have functionalities in a multitude of material applications, including smart actuator materials for MEMS and small robotics, superior conducting polymers, folded sensors and catalysts, tailored silk and adhesive polymers and opto-electronic materials.

Research Topic Contact: Dr. Clifford Lau, ODUSD(LABS), 703-696-0366, clifford.lau@osd.mil

FY03 MURI topic #12
Submit white papers and proposals to the Director of Basic Research

Laboratory Instrumentation Design Research

Background: In his book *Imagined Worlds* (Harvard University Press, 1977), Freeman Dyson writes that, *"the effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained."* In this spirit, the focus of this MURI topic is the beginning of a systematic and sustained effort towards the development of the next generation of research tools. The goal of each funded project is not simply to design an instrument, but an instrument or device having precise design specifications, assembly procedures, and process specifications that will allow it to be readily replicated by other university teams. The unique scientific application and exploitation of novel characteristics and phenomena needs to be emphasized. The funded instrument development project will be highly collaborative. Instrument and device developers must collaborate with design and manufacturing engineers in order to achieve high-performance instruments and devices that not only operate, but have also incorporated such desirable features as reliability, operability, maintainability, and affordability. An associated goal of the program is to enhance the development of a new cadre of scientists and engineers who are experts in, and place high intellectual value, in the art and science of building instruments, devices, and equipment. Proposed projects must describe the educational impact of the project on students not only in the Principal Investigator's research area, but also on collaborating engineering students in the areas of design and manufacturing.

Objectives: To investigate the next generation of research tools to allow us to make scientific measurements that we have not been able to do, and to develop a new generation of scientists and engineers with expertise in the design and manufacturing of innovative instruments and devices.

Research Concentration Areas: The topic is intended for innovative ideas in instruments and devices that would transform the way we do scientific investigations. Incremental upgrades of existing instruments and devices will not be considered. The following are examples of the kind of proposed projects that will receive consideration. Other innovative proposals that address the objectives of this topic are highly encouraged.

(1) Instrumentation for Designer Photon Sources and Detectors. To realize the full potential of quantum information processing, many components must be developed. For example, quantum cryptography, quantum communication via teleportation, and linear-optics based quantum computing all depend on the availability of single photon sources and detectors. In addition to N=1 Fock state single photon sources and detectors, on-demand sources of designer entangled photons, and perhaps GHZ photon states, are required. Furthermore, it will be necessary to develop instrumentation to measure the degree of photon entanglement and a device that can perform measurements in all Bell basis states. Finally, quantum registers and quantum repeaters are needed to store, purify, and release single and entangled photons on demand. Active and passive quantum error correction and avoidance may be required. Successful proposals must develop at least three of the following components. 1) On-demand sources of single and entangled photons at selectable wavelengths, especially those that may be transmitted through optical fiber at high data rates (>1 MHz). Individual photons should be emitted into a single spatial mode and should be able to couple to single mode optical fiber. 2) Efficient detectors of single photons and photon pairs at these same wavelengths and data rates. 3) Instrumentation for generating arbitrarily entangled photons and for measuring the degree of entanglement of two or more photons. 4) Instrumentation to measure entangled photons in all Bell-basis states. 5) Quantum registers and quantum repeaters to store, purify, and release single and entangled photons on demand. Point of contact: Henry Everitt, Army Research Office, 919-549-4369, everitt@aro.arl.army.mil

(2) Nanoprobe Tools and Instruments. The recent rapid advances in nanotechnology are due in large part to our newly acquired ability to measure and manipulate individual structures on the nanoscale. Whether it be scanning probes, optical tweezers, high-resolution electron microscopes, or other new tools, instruments available to researchers now permit them to create new structures, measure new phenomena, and explore new applications. The inventions of the scanning tunneling microscope (STM) and the atomic force microscope (AFM) have spawned development of a variety of new scanning probe microscopes (SPMs). The objective is to advance nanoscale science and technology through the development of nanoprobe instruments with unprecedented capability. Research focus areas include but not limited to: (1) Miniaturized instruments for the analysis of supramolecules, biomolecules, and polymers at the individual molecules level; (2) Instrument for sub-surface imaging and characterization; (3) Nanoprobes for chemical identification of unknown material and nanostructures; (4) Multifunctional parallel probe arrays that would provide a “laboratory on a tip,” or “nanoscale total analysis”; (5) Instrument for locating and maintaining a position with nanometer accuracy and precision for use in nanoelectronic device fabrication; (6) Single molecule spectroscopy as an optical nanoprobe that allows the experimentalist to sample inside the molecule ensemble average, obtaining information at the level of the individual molecule; and (7) Devices for the measurement and nondestructive monitoring the submonolayer control of superlattice growth.
Point of contact: Gernot S. Pomrenke, AFOSR/NE, 703-696-8426, gernot.pomrenke@afosr.af.mil

(3) Next Generation Epitaxy. Epitaxy is the cornerstone of current semiconductor material and device development. However, current equipment is extremely expensive, complicated, and often unpredictable. Molecular beam epitaxy and metal-organic chemical vapor deposition are the current champions of epitaxy, but their high cost prevents their use at many universities and small businesses. A new epitaxial reactor design paradigm based on microfabrication related technology, coupled with in-situ characterization techniques, and leveraging extensive process modeling groundwork, has high potential to accelerate research in a wide range of compound semiconductor materials. New instruments that integrate reactant delivery, surface reaction control, and in-situ characterization based on microfabrication techniques are sought for epitaxial reactors that are simple to use, low-cost, and capable of growing diverse materials with a changeover time less than current methods. Research areas include but not limited to: (1) Instrument for integrating reactant control functions such as the metering and purification of a variety of reactants using distributed, controllable, wafer-scale microstructures; (2) Instrument for surface reaction control functions including surface bond site preparation (e.g. optical emitter arrays interacting with surface bonds, periodic extension of evanescent waves from the substrate) and surface migration (e.g. optical emitter arrays to bias adatom thermal motion toward a surface step); and (3) Distributed array of probes to determine the state (composition, defect density, thickness, etc.) of a growing layer, suitable for closed-loop feedback control and to characterize the physical (thickness, composition, etc.), electrical (doping density, etc.) and optical properties (absorption band edge, luminescence peak position and width, etc.) of the epitaxial layers. Point of contact: LtCol Todd Steiner, AFOSR, 703-696-7314, todd.steiner@afosr.af.mil

Impact: A new way of thinking about instruments and devices that would allow us to make scientific measurements that we have not been able to do before, and would enable unprecedented advances in research and development. The projects funded in this topic will also enhance the development of a new generation of scientists and engineers with expertise in the design of instruments that are easy to operate, reliable, manufacturable, and affordable.

Research Topic Contact: Dr. Clifford Lau, ODUSD(LABS), 703-696-0366, clifford.lau@osd.mil

Submitted in response to FY 2003 DoD Multidisciplinary Research Program of the University Research Initiative BAA

APPENDIX A: PROPOSAL COVER
(This form must be completed and submitted as the cover of the proposal)

PROPOSAL NUMBER:_________________
(to be completed by DoD Only)

1. THE PRINCIPAL INVESTIGATOR (One name only)

____ ______________________________________
(Title) (First Name) (MI) (Last Name) PI Signature (please use blue ink)

(______)__________________ (_______)___________________ _________________________________
(Phone Number) (FAX Number) (E-mail address)

____
(Institution)

____
(Department/Division)

____
(Street/PO Box/Building)

____
(City) (State) (Zip Code)

CURRENT DoD CONTRACTOR OR GRANTEE: YES_____NO_____

If yes, give Agency, Point of Contact, Phone Number:____

____
2. THE PROPOSAL:

____
(Title; be brief and descriptive; do not use acronyms or mathematical or scientific notation)

<u>1 MAY 2003 to 30 APR 2006</u> <u>1 MAY 2006 to 30 APR 2008</u> _______________________________
Proposed Base Period Proposed Option Period Your Institution's Proposal Number

Submitted to: ___________ _______ ____
DOD Agency/ Topic #/ Topic Title

Total funds requested from DOD:

_____________ + ________________ = ____________________
3-year base total 2-year option total 5-year total

OTHER AGENCIES RECEIVING THIS RESEARCH FUNDING REQUEST
(e.g., NSF, DOE, NASA, NIH). Please identify agency(ies) and give Name(s) and Phone Number(s) of Point(s) of Contact at those agencies:

____

3. CERTIFICATIONS: By signing and submitting this proposal, the proposer is providing the certification at Appendix A to 32 CFR Part 25 regarding debarment, suspension, and other matters; the certification at Appendix C to 32 CFR Part 25 regarding drug-free workplace; and the certification at Appendix A to 32 CFR Part 28 regarding lobbying.

4. MINORITY INSTITUTION: _____ Check here if the academic institution named above is qualified to be identified by the Department of Education as a minority institution (i.e., a historically Black college or university, Hispanic-serving institution, Tribal college or university, or other institution meeting statutorily-defined criteria for serving ethnic groups that are underrepresented in science and engineering). The Department of Education maintains the list of U.S. accredited postsecondary institutions that currently meet the statutory criteria for identification as minority institutions at the following web site: http://www.ed.gov/offices/OCR/minorityinst.html

5. THE INSTITUTION: NAME AND ADDRESS OF UNIVERSITY OFFICIAL AUTHORIZED TO OBLIGATE CONTRACTUALLY AND WITH WHOM BUSINESS NEGOTIATIONS SHOULD BE CONDUCTED:

____
(Title) (First Name) (MI) (Last Name)

(______)_______________ (_______)_________________ _______________________________
(Phone Number) (Fax Number) (E-mail address)

____
Name of Grantee (University)

____
Street Address (P.O. Box Numbers Cannot Be Accepted)

____
(City) (State) (Zip Code)

Taxpayer Identification No. (TIN)[1]______________________DUNS No.[2]______________________

_______________________________________ _______________
Signature of Authorized University Official Date
(Please use blue ink)

[1] The DoD is required by 31 U.S.C. 7701 to obtain each recipient's TIN (usually the Employer Identification Number) for purposes of collecting and reporting on any delinquent amounts that may arise out of the recipient's relationship with the Government.

[2] The institution's number in the data universal numbering system (DUNS) is a unique nine digit (all numeric) identification number for organizations. Dun & Bradstreet Corporation assigns it. You can receive a DUNS number by calling Dun & Bradstreet at 1(800) 333-0505 or go to the Dun & Bradstreet Web site at http://www.dnb.com/dnbhome.htm.

Appendix B: Acknowledgment

Affix
Proper
Postage!

FROM:

TO:

(Instructions: Please fold in half so that this text is on the outside of the page and tape the open edges, enter your return address in the FROM: section, enter the University Contact name and address in the TO: section, place a stamp over the AFFIX PROPER POSTAGE section, and submit with your proposal)

Date:

Dear Proposer:

Your FY2003 Multidisciplinary URI research proposal has been received at:

ARO ____   ONR _____   AFOSR _____   DARPA ______

____and will be evaluated, Control Number______________

____will not be evaluated for the following reason(s):

Letters announcing award recommendations will be mailed by about 14 February 2003.